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Sewage Sludge Incinerator
Fuel Reduction, Hartford
Connecticut

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SEWAGE SLUDGE INCINERATOR

FUEL REDUCTION

HARTFORD, CONNECTICUT

by

Albert J. Verdouw
Eugene W. Waltz
Indianapolis Center for Advanced Research
Indianapolis, Indiana 46204

and

Paul F. Gilbert
Hartford Metropolitan District Commission
Hartford, Connecticut 06101

for

Battelle Columbus Laboratories
Columbus, Ohio 43201

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Project Officer
Howard O. Wall
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

The U. S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

Incineration is an ultimate disposal option that provides an inert, safe, minimum-volume residue that minimizes ultimate landfill requirements. This disposal method is expected to find increasing use as landfill sites become less available and as ocean disposal is phased out for environmental reasons. Auxiliary fuel requirements for incinerators are of great concern because of the increasing costs of all fossil fuels. This report presents the results of a field demonstration project to reduce fuel consumption in municipal sludge incinerators by using more advanced sludge dewatering equipment and a more fuel-efficient operating mode.

Francis T. Mayo, Director
Municipal Environmental Research
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16. ABSTRACT A field demonstration project was conducted at Hartford, Connecticut, which showed that the supplemental fuel usage for sewage sludge incineration could be reduced 83%. This was accomplished by using a belt press filter for dewatering which reduced fuel usage 65% and then fuel efficient burning procedures and operator training further reduced that amount 51%. The Hartford plant originally used 122 gallons of fuel per ton of dry sludge burned, now it uses about 22 gallons of fuel per dry ton burned. Essentially all the 22 gallons of fuel are used to keep the incinerators warm on the weekend when sludge is not burned.			
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ABSTRACT

A field demonstration project was conducted to reduce fuel consumption in municipal sludge incinerators by using a more fuel-efficient operating mode. The Hartford Metropolitan District Commission demonstrated the new operating mode at its Hartford Water Pollution Control Plant using three conventional multiple-hearth sludge incinerators.

The fuel-efficient incinerator operating mode was developed from an extensive program of combustion engineering measurement, testing, and operational analysis. Incinerator operators were then given on-the-job training in the new operating mode during a 14 day demonstration test period. After 12 months of routine operations with the new operating mode, a fuel reduction of 51% was achieved, representing fuel cost savings of approximately \$250,000 per year.

The Hartford Water Pollution Control Plant had just completed a conversion of its sludge dewatering equipment from vacuum filters to continuous-belt filter presses when this project was initiated. The conversion to belt filter presses had already resulted in major fuel savings, reducing the average specific fuel consumption by more than 65%. The fuel reduction achieved from using the new operating mode was in addition to these savings from dewatering.

Together, the annual fuel cost savings from dewatering and improved incinerator operation amounted to \$1.3 million. The Hartford experience demonstrates very clearly the relative contributions that both dewatering improvements and incinerator operating mode can have on reducing fuel consumption in multiple-hearth incinerators. This experience also shows that even when the dewatering process has been substantially improved, further efforts to improve the incinerator operating mode are very cost effective.

Comparisons of fuel reductions achieved in four major cities through use of new incinerator operating modes are also reported.

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CONTENTS

Foreword	iii
Abstract	iv
Figures	vi
Tables	vii
English to Metric Units Conversion Chart	viii
Acknowledgments	ix
1. Introduction	1
2. Conclusions	2
3. Recommendations	3
4. Description of Previous Operations	4
Dewatering Equipment	4
Incinerator Description	4
Past Operational Performance	6
5. Belt Filter Presses	11
Testing and Installation	11
Operational Experience	12
Fuel Reduction Results	13
Cost Savings	15
6. New Incinerator Operating Mode	16
Operational Measurements and Analysis	16
New Operating Mode	19
Fuel Reduction Results	19
7. Total Fuel Reduction and Cost Savings	38
Total Fuel Reduction	38
Total Cost Savings	40
8. Comparison of Results in Four Major Cities	41
References	45

FIGURES

<u>Number</u>		<u>Page</u>
1	Hartford Incinerator System Schematic	5
2	Specific Fuel Consumption Correlation With Sludge Cake Moisture To Volatile Ratio for the Baseline Period	8
3	Specific Fuel Consumption Before and After Belt Filter Presses	14
4	Pressure Measurement Locations	17
5	Incinerator Operating Mode Summary	20
6	Incinerator Standby Operating Mode Summary	21
7	Correlation of Specific Fuel Consumption with Incinerator Load Rate for the Baseline Period	30
8	Correlation of Specific Fuel Consumption with Sludge Cake Moisture to Volatile Ratio for the Baseline Period	31
9	Overall Demonstration Test Fuel Reduction Results . . .	32
10	Demonstration Test Fuel Reduction Results by Operating Mode with Load Rate Correction	33
11	Demonstration Test Fuel Reduction Results by Incinerator Load Rate	34
12	Demonstration Test Fuel Reduction Results by Sludge Cake M/V Ratio	35
13	Specific Fuel Consumption Versus Sludge Cake M/V Ratio Before and After Incinerator Operating Mode Change . .	37
14	Average Specific Fuel Consumption for 1978 to 1982 . .	39
15	Specific Fuel Consumption Versus Sludge Cake M/V Ratio for Indianapolis, Hartford, Buffalo and Nashville	43

TABLES

<u>Number</u>		<u>Page</u>
1	Daily Average Values of Key Operating Variables for Past Operations	7
2	Daily Average Values of Key Operating Variables by Month for the Baseline Period	9
3	Daily Average Values of Key Operating Variables by Incineration/Dewatering Mode for the Baseline Period . .	10
4	Overall Operational Guidelines	22
5	Incinerator Control Summary	23
6	General Operating Procedure	24
7	Specific Settings for Normal Operation	25
8	Rising Fire and "Burnout" Control Techniques	26
9	Standby Operation and Start-Up Procedure	27
10	Dropping Fire Control Techniques	28
11	Average Specific Fuel Consumption and Sludge Cake M/V Ratio for 1978 to 1982	38
12	Key Operating Features of Subject Cities	41
13	Fuel Reduction Achieved in Four Major Cities from Improved Incinerator Operating Modes	42

METRIC CONVERSION TABLE

<u>English Unit</u>	<u>Metric Equivalent</u>	<u>Conversion Factor</u>
Pound (lb)	Kilogram (kg)	0.4536
Short Ton (ton)	Metric Ton (m. ton)	0.9072
Cubic Feet (ft ³)	Cubic Meter (m ³)	0.0283
Gallon (U.S.) (gal)	Liter (ℓ)	3.785
British Thermal Unit (Btu)	Joule (j)	1055
Fahrenheit (°F)	Centigrade (°C)	5/9 (°F - 32)

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The success of the project was due in part to the appropriate application of combustion engineering operating technology to the Hartford incinerator operations. Major credit, however, goes to the progressive and innovative management of the Hartford Metropolitan District Commission staff of Mr. Michael A. Reardon, General Manager, and Mr. Paul Gilbert, Plant Engineer. The operating personnel of the Hartford Water Pollution Control Plant helped make this project a success and are continuing to operate the plant as one of the most energy-efficient wastewater treatment plants in the United States.

SECTION 1

INTRODUCTION

The disposal of municipal sewage sludge by incineration most often requires the use of major amounts of auxiliary fuel. Increasing energy costs have made incinerator fuel consumption a major operational cost problem for many municipal operations. The objective of this project was to demonstrate how incinerator fuel consumption can be reduced by developing and using a more fuel-efficient operating mode. This demonstration was even more significant in Hartford, Connecticut, because the Hartford Metropolitan District Commission had already converted its water pollution control plant to the use of belt filter presses for improved sludge cake dewatering. The Hartford Water Pollution Control Plant was one of the first plants in the United States to use these presses. The conversion to continuous belt filter presses had already resulted in major fuel savings from the dramatic improvement in sludge cake dewatering. The Hartford Metropolitan District Commission then conducted this project to achieve further fuel reductions through improved incineration efficiency at its main plant with the technical assistance of the Indianapolis Center for Advanced Research.

A new, more fuel-efficient operating mode was developed from combustion engineering analyses and reduced to practice. Fuel consumption performance tests were conducted to demonstrate possible reduction levels and to provide on-the-job training for incinerator operators.

Since the Hartford Water Pollution Control Plant was one of the first operations in the U. S. to place the belt filter press technology into full-scale operation, the experience and results achieved with the belt presses are also reviewed in this report.

SECTION 2

CONCLUSIONS

1. Fuel consumption in multiple-hearth incinerators can be significantly reduced by improving dewatering equipment and also by optimizing existing incinerator operating modes with more fuel-efficient operating techniques.
2. A conversion from vacuum filters to continuous belt filter presses resulted in a 65% fuel reduction.
3. The use of a new incinerator operating mode in routine operations achieved an additional 51% fuel reduction and a reduction in equipment maintenance problems.
4. Reduction in fuel use from dewatering and incinerator operation improvements resulted in annual cost savings of approximately \$1.3 million.

SECTION 3

RECOMMENDATIONS

- Most municipal sludge incinerator operations are still experiencing high fuel consumption rates as a result of using improper incinerator operating modes. Further applications of improved operating techniques need to be promoted as a cost effective approach to reducing incinerator fuel consumption.
- Empirical investigation of alternative internal rabbling patterns for multiple hearth incinerators should be undertaken to find the optimum pattern for dryer sludge cakes being produced by improved dewatering equipment.
- A comparative analysis of specific fuel consumption with sludge cake moisture and volatile characteristics for various municipal operations needs to be undertaken to exemplify the enormous fuel-saving potential that still exists in many incinerator operations.
- Existing installations can make low-cost investments for improved instrumentation and controls and operator training programs to obtain major fuel savings.

SECTION 4

DESCRIPTION OF PREVIOUS OPERATIONS

The Hartford Water Pollution Control Plant was one of the first plants in the United States to place the belt filter press technology into full-scale operation to help reduce sludge incinerator fuel consumption. For this reason, the results obtained by improved dewatering equipment also reviewed in this report along with the results achieved by improved incinerator operating modes. These two major operational improvements have made the Hartford sludge disposal operations one of the most energy-efficient in the country.

DEWATERING EQUIPMENT

The Hartford Water Pollution Control Plant performs primary and secondary wastewater treatment for more than 60 million gallons of wastewater per day and generates in excess of 300 wet tons of filtered sludge cake per day. The sludge-handling facility was designed in 1968 with four dissolved-air flotation thickeners, five drum-type vacuum filters, and three multiple hearth incinerators.

In March 1979, the first continuous-belt filter press was installed. Despite numerous mechanical problems and excessive downtime (25%), the belt filter press quickly proved itself to be economically beneficial. The first press resulted in substantial fuel savings, but a higher degree of mechanical reliability, simpler design, and higher performance criteria were sought for additional presses. The second belt press was acquired and installed in December 1979 after side-by-side performance tests were made of three major belt filter presses. The plant operated the first half of 1980 with two presses and one vacuum filter resulting in further fuel savings and solids production improvements. A third press was then installed in December 1980. To provide further operational flexibility, a fourth press was installed in June 1982.

INCINERATOR DESCRIPTION

Like most other cities using incineration for sludge disposal, Hartford uses multiple-hearth-type incinerators. The main plant has three incinerators operating on 5-days a week, 24 hours a day. The incinerators have 11 hearths and are 22.3 feet in diameter. The design loading rate is 12.5 wet tons of sludge cake per hour per incinerator. The Hartford incinerator system is shown schematically in Figure 1.

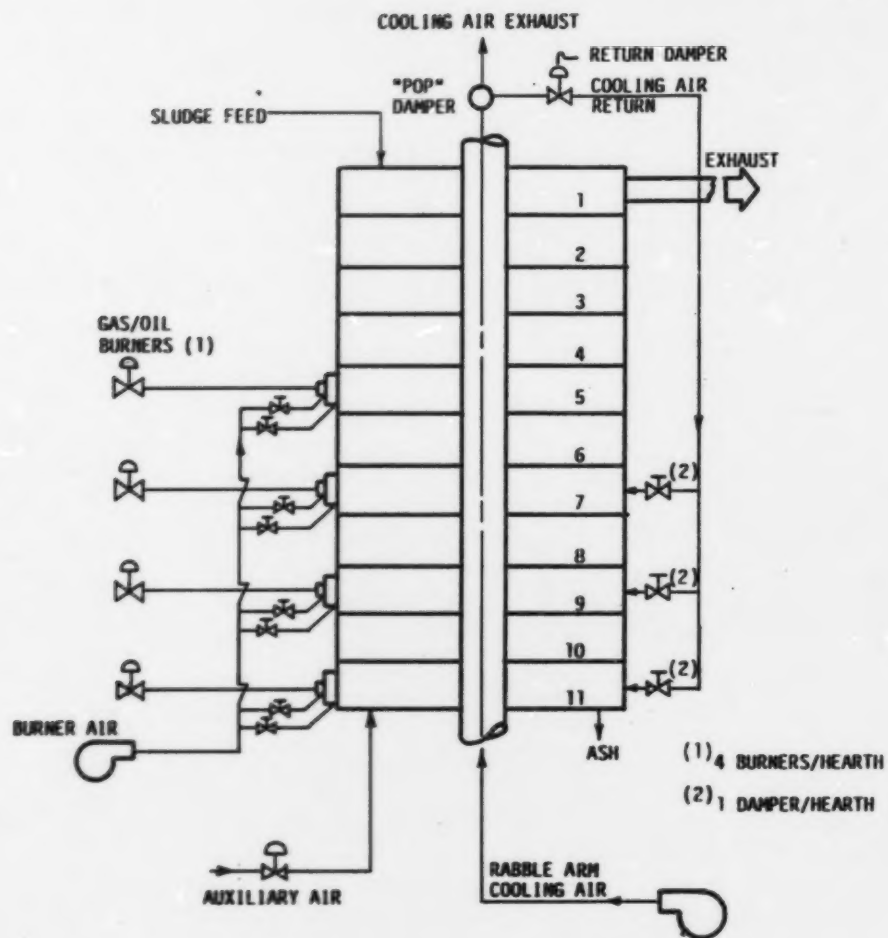


Figure 1. Hartford Incinerator System Schematic

Sludge cake enters the incinerator through a top-mounted drop chute. The sludge cake is moved down through the incinerator from hearth to hearth by rabble arms with raking teeth connected to a rotating center shaft. The sludge cake dries in the upper hearths by exposure to the high temperature combustion gases and then burns on the middle hearths. The hot ash cools and is discharged from the bottom of the incinerator where it is water quenched. The central shaft and rabble arm are air-cooled with the heated cooling air emerging from the incinerator at 300°F.

The incinerators have twelve dual fuel (gas or oil) fired burners with three each located on hearths 5, 7, 9 and 11. The burners are excess-air type burners, with constant atomizing and combustion airflow over the firing range. The atomizing and combustion airflows are adjustable at each burner. Additional air can also be supplied by the heated rabble arm cooling return air, auxiliary combustion air and through open hearth doors and peep holes. As shown in Figure 1, the heated rabble arm cooling air can be returned to the incinerator at the 7, 9 and 11 hearth levels, or discharged to the atmosphere.

There was no common operating procedure being used by the Hartford incinerator operators. Each operator had certain specific practices and techniques for maintaining temperatures on various hearth levels and for managing incinerator airflow. Preliminary investigations of the operator-specific operating modes identified several common operating problem conditions relative to fuel consumption. These were:

- incinerator exhaust temperatures were too high
- combustion zone location was too high in the incinerator
- incinerator draft was greater than necessary
- heated rabble arm cooling return air was under utilized
- burner use patterns were not optimum

Also contributing to high fuel consumption were other problem areas associated with the degree of remote operator controls for airflow dampers and burners.

PAST OPERATIONAL PERFORMANCE

A statistical analysis was made of past operational data to provide an accurate baseline of the fuel reduction achieved by the conversion to belt filter presses and by improvements in the incinerator operating mode. The historical period from 1978 through August 1981 was analyzed to compute the average load rates, sludge cake characteristics and fuel consumption performance. The operational data analyzed included daily average values for the following (see Table 1):

- total wet pounds of sludge cake
- percent moisture
- percent volatiles
- fuel used for incineration
- operational hours
- dewatering/incineration mode

Operational correlations were made of specific fuel consumption (SFC) with sludge cake moisture to volatile ratios (M/V) and incinerator loading rates. These computations were made for a period of 15 months between 1980 and 1981 to serve as a baseline for comparing the fuel reduction achieved from changing the incinerator operating mode alone. Figure 2 shows the correlation plot for SFC versus sludge cake M/V ratio for the baseline period. Table 2 lists the values for the key variables by month, and Table 3 shows the same information by dewatering/incineration mode.

TABLE 1. DAILY AVERAGE VALUES OF KEY OPERATING VARIABLES FOR PAST OPERATIONS

<u>VARIABLE</u>	<u>1978</u>	<u>YEAR</u>		<u>1981</u>
		<u>1979</u>	<u>1980</u>	
BELT PRESSES OPERATING	0	1	2	3
SLUDGE CAKE:				
Percent Solids	13.8	14.4	18.5	19.4
Percent volatiles	77.1	73.7	77.1	78.3
M/V Ratio	8.58	8.15	5.82	5.37
SPECIFIC FUEL CONSUMPTION (Gallons of Oil)				
Per Wet Ton	16.4	16.4	10.6	8.3
Per Dry Ton	125.0	116.0	60.5	43.5
Per Volatile Ton	162.0	157.0	78.3	56.0

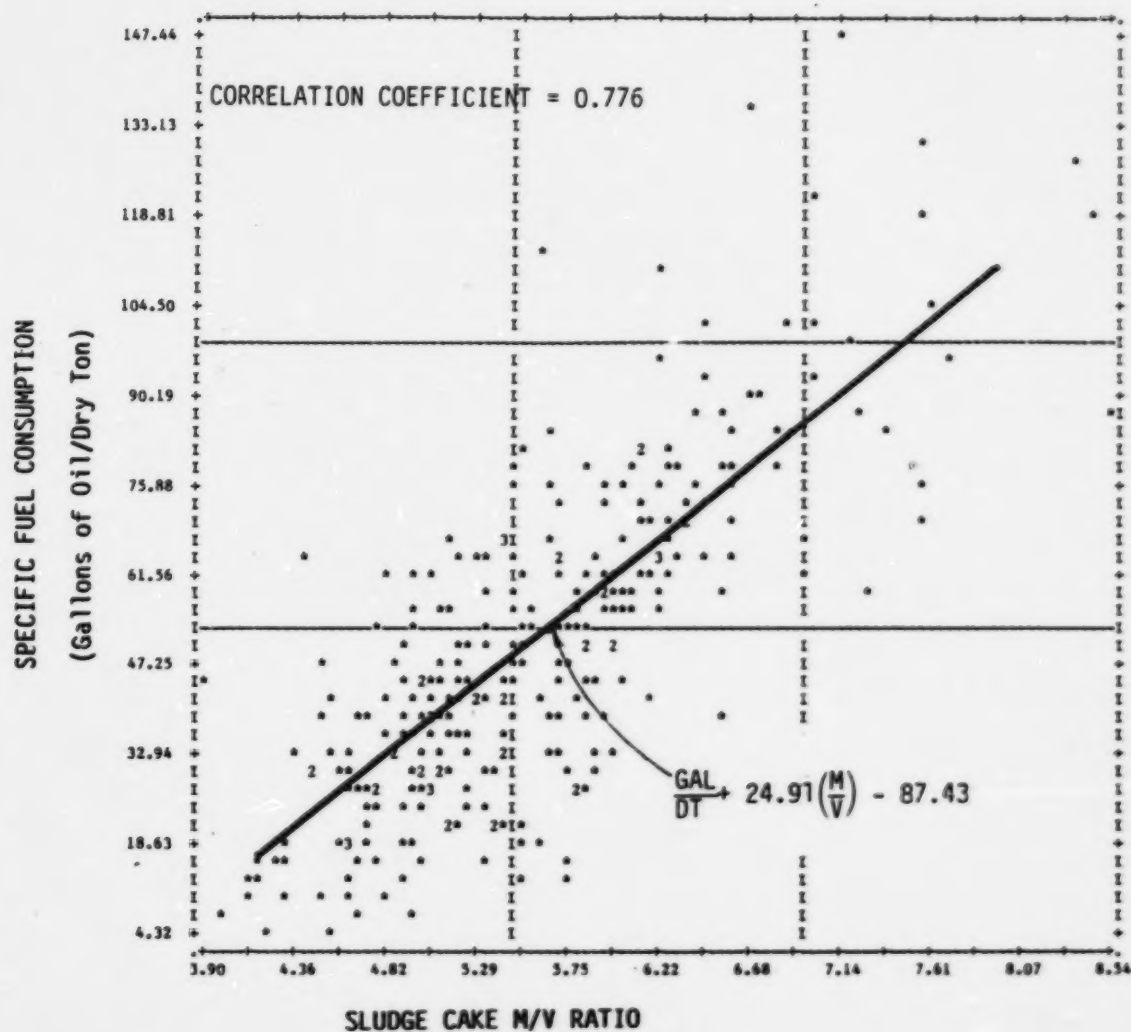


Figure 2. Specific Fuel Consumption Correlation With Sludge Cake Moisture To Volatile Ratio For The Baseline Period

TABLE 2. DAILY AVERAGE VALUES OF KEY OPERATING VARIABLES
BY MONTH FOR THE BASELINE PERIOD

MONTH	SPECIFIC FUEL CONSUMPTION				SLUDGE CAKE CHARACTERISTICS				SLUDGE CAKE LOAD RATES					INCINERATOR TIME Hours Per Day
	Gallons of Oil Per				% M/V				Tons Per Day					
	Wet Ton	Dry Ton	Vol Ton	Per Ton	H ₂ O	%	Vol Ratio	Wet Ton	Dry Ton	Vol Ton	Wet Ton	Dry Ton	Vol Ton	
June, 1980	11.4	63.0	83.0		81.7	76.1	5.9	194	36	27	7.0	1.3	1.0	28.5
July	11.4	68.4	92.9		82.1	73.3	6.4	218	39	28	6.7	1.2	0.9	28.8
August	4.5	21.5	29.1		78.4	74.3	4.9	188	41	30	8.1	1.8	1.3	35.8
September	9.9	51.7	67.6		80.3	76.7	5.4	258	50	38	6.8	1.3	1.0	23.3
October	11.1	62.1	78.5		81.6	79.3	5.7	265	49	38	6.5	1.2	0.9	39.9
November	15.1	94.5	116.7		83.8	80.9	6.4	246	39	32	5.7	0.9	0.7	41.8
December	10.5	61.0	76.8		82.6	79.7	6.0	311	53	43	8.0	1.4	1.1	43.2
January, 1981	7.7	40.1	48.8		80.7	82.3	5.1	326	62	51	8.9	1.7	1.4	40.2
February	7.6	38.4	49.9		80.1	77.0	5.3	259	51	39	8.0	1.6	1.2	38.0
March	8.1	41.2	52.0		80.2	79.2	5.2	223	44	34	8.0	1.6	1.3	35.2
April	6.5	32.3	40.4		79.5	80.0	4.7	272	56	44	9.2	1.9	1.5	32.1
May	6.0	29.5	37.8		79.7	78.3	5.0	237	48	37	6.7	1.4	1.1	32.0
June	8.4	45.6	58.5		81.0	78.3	5.5	191	36	28	6.5	1.2	1.0	36.5
July	11.5	66.2	90.1		82.3	73.5	6.4	257	45	33	5.9	1.0	0.8	31.0
August	9.0	46.7	59.4		80.3	79.2	5.2	248	48	38	6.3	1.3	1.0	44.2
														40.6
Average	9.4	51.7	66.8		81.0	77.8	5.6	246	46	36	7.2	1.4	1.1	36.2
Maximum	23.6	147.4	200.3		87.0	88.3	8.5	506	96	77	15.3	3.2	2.4	48.0
Minimum	1.0	4.3	5.1		75.0	69.1	3.9	78	15	11	3.3	0.5	0.4	9.0

TABLE 3. DAILY AVERAGE VALUES OF KEY OPERATING VARIABLES BY INCINERATOR/DEWATERING MODE FOR THE BASELINE PERIOD

OPERATIONAL VARIABLE	ALL MODES	DEWATERING/INCINERATION MODE				1978-79 VACUUM FILTERS ONLY
		1 Inc. 2 Presses	2 Inc. 3 Presses	Other Combinations		
<u>Specific Fuel Consumption</u>						
a) Gallons of Oil Per Wet Ton	9.4	6.1	9.6	11.7	16.7	
b) Gallons of Oil Per Dry Ton	51.7	31.5	50.0	66.7	121.8	
c) Gallons of Oil Per Volatile Ton	66.8	40.6	64.4	86.2	160.5	
<u>Sludge Cake Characteristics</u>						
a) Percent Moisture	81.0	79.9	80.5	82.0	86.3	
b) Percent Volatiles	77.8	77.8	78.1	77.4	75.9	
c) Moisture/Volatile Ratio	5.59	5.18	5.35	5.96	8.43	
<u>Sludge Cake Load Rates</u>						
a) Wet Tons Per Day	246	182	268	284	312	
b) Dry Tons Per Day	46	37	52	51	43	
c) Dry Volatile Tons Per Day	36	28	41	40	32	
d) Wet Tons Per Incinerator Per Hour	7.2	8.1	6.4	6.6	6.7	
e) Dry Tons Per Incinerator Per Hour	1.37	1.61	1.18	1.16	0.92	
f) Dry Volatile Tons Per Incinerator Per Hour	1.06	1.26	0.99	0.93	0.70	

SECTION 5

BELT FILTER PRESSES

TESTING AND INSTALLATION

The Hartford Metropolitan District began pilot testing the belt filter press technology in Spring of 1978. Test results showed significantly drier sludge cake was produced at higher production rates as compared to the performance of the existing vacuum filters. The District then conducted a continuous 24 hour side by side performance test with the two most qualified bidders to select the first press for procurement and installation. The minimum performance test criteria were the following:

- production rate - 2000 dry pounds per hour
- discharge cake solids - 28% minimum
- sludge conditioning - 90 pounds maximum liquid polymer per dry ton
- capture rate - 95%
- sludge feed - 4.0% to 4.3% solids (based on a sludge blend 65:35 activated sludge to raw sludge volume)

In March, 1979, the District installed the first belt filter press with a carefully monitored start-up and shake-down period. Despite numerous mechanical problems and excessive downtime (25%), the belt filter press quickly proved itself so economically beneficial the approval for acquiring a second press was granted only four months after the first one was installed.

In selecting the second press, performance tests were again conducted with a two fold purpose. The District wanted to evaluate, not only overall performance, but also the mechanical design and maintenance features of the presses to incorporate these requirements in the bid specifications. The second press was supplied by a different manufacturer from the first.

During the first half of 1980, the Hartford plant operated with two belt presses and one vacuum filter. The mechanical reliability sought with the second press was realized, as well as, continued fuel savings and sludge cake production improvements. With this continued operational success, the District purchased its third press from the supplier of the second press and installed it in December, 1980. With the third press installed, the plant was then able to operate exclusively with belt filter presses. A fourth press was then purchased and placed into operation in June, 1982.

OPERATIONAL EXPERIENCE

Hartford was one of the first major municipal wastewater treatment plants in the country to put the continuous belt filter press into routine operations. The initial operation of the first press on a continuous 24 hour-a-day production basis was plagued with numerous mechanical problems. Typical problems encountered were with the bearings, spray water pump, filter screen cleaning and filter screen tracking. With assistance from the manufacturer, the first press was retrofitted and upgraded for more reliable operation. The second, third and fourth presses were supplied by a different manufacturer and have had few mechanical problems with satisfactory operation.

When specifications were written for the first press, Hartford had no experienced press operators to contact regarding screen life, wearing characteristics, seam design, etc. Screen life was a major concern, and the press suppliers were required to furnish replacement screens for two years after installation. Each press has an upper and lower screen, traveling together, to "sandwich" the sludge as it is being pressed. The majority of screens are joined together by stainless steel clips connected with a piece of wire or nylon monofilament. The screen material is a polyester with weaves, meshes and working stresses varying according to type and supplier. The most critical component of the screen is the seam closure. Operating experience showed that the cyclical contact of the screen between the discharge scraper blade and the seam closure often wore the clipper seam, causing premature failure. To overcome this problem, the linen phenolic scraper blades were converted to high molecular weight plastic blades, resulting in increased screen life. The new plastic blades were softer, reducing the wear and tear when contacting the seam closure. This conversion increased the screen life from an initial average of 500 hours to an average of 1,500 hours.

For sludge conditioning during the pilot testing phase, the presses required polymer dosages equal to 20 to 25% more than what had been required with vacuum filters. Further testing and experimentation with the polymer supplier resulted in the use of a two component liquid polymer mix which reduced the dosage required to the same level as was required for the vacuum filters. Proper polymer conditioning, on all the presses, has been a problem. Changes in the sludge conditioning tank for improving the polymer sludge mixing have reduced polymer dosages and increased flexibility to adjust to varying sludge characteristics.

Seventy percent of the sludge being fed to the presses on a volume basis is thickened waste activated sludge from the Hartford, Rocky Hill and East Hartford plants. The 30% balance of sludge is raw primary from Hartford. Maintaining a constant blend in mixing these sludges for pumping to the presses requires close operator attention and control. Sludge blend variations of only 5% to 10% can cause the press screens to plug and the sludge to squeeze out the ends of the rollers. This results in both a sharp decrease in the percent solids and production. Careful monitoring of the sludge inventory is required to dictate the type and the amount of sludge to be pumped to the mixing tanks to maintain a 70% activated sludge blend to the presses at all times.

In spite of these operating problems associated with reducing to practice a new dewatering technology and equipment, the operational improvements and cost savings achieved with the presses at the Hartford plant have been dramatic as discussed in a later section. The Hartford Plant Engineering staff is continuing to experiment in several ways to further improve the press operation, including:

- Evaluation of press screens of different designs to increase sludge dryness and production.
- Installing chicane devices in the gravity section of the presses to furrow and turn over the sludge to increase the drainage rate.
- Varying the polymer addition points to determine how much sludge conditioning is necessary.
- Experimenting with rotary sludge thickeners to produce heavier sludge concentrations to the presses to obtain an even drier cake.

FUEL REDUCTION RESULTS

Before 1982, Hartford had three belt presses and three incinerators enabling two basic dewatering/incineration operating modes to be used depending on plant loading requirements: two presses feeding one incinerator or three presses feeding two incinerators. Operating data for the 1978 to 1981 time period were analyzed by dewatering/incineration mode. The comparison of the key plant performance variables when using belt presses in two different modes over the 1979 to 1981 time period versus the use of vacuum filters only during 1978-1979 is shown in Table 3 and Figure 3.

As shown in Table 3 and Figure 3, the improved dewatering from the belt filter presses as compared to vacuum filters was dramatic in reducing specific fuel consumption (SFC) and increasing incineration rates (production). The most effective operating mode was two presses operating and feeding one incinerator. The percent difference between these two operating modes for the key variables is shown in Table 3. The fuel consumption was reduced by 65% on a dry ton basis! The improvement in dewatering is not only shown by the increase in percent solids, but is more directly reflected in the 38.6% decrease in the sludge cake moisture to volatile ratio which is the principal determinant of specific fuel consumption. The highly correlated relationship between the specific fuel consumption and the sludge cake moisture to volatile ratio was also computed for the baseline time period and is shown in Figure 2. The rate of change of SFC with the sludge cake M/V was 24.9 gallons of oil per dry ton of sludge cake incinerated. This rate of change reflects the thermal efficiency of the given incinerator equipment design and operational set-up and how it is specifically being operated. The incinerator operating mode related changes which achieved further fuel reductions from improving the thermal operating efficiency of the incinerators is discussed in the second major section of this report.

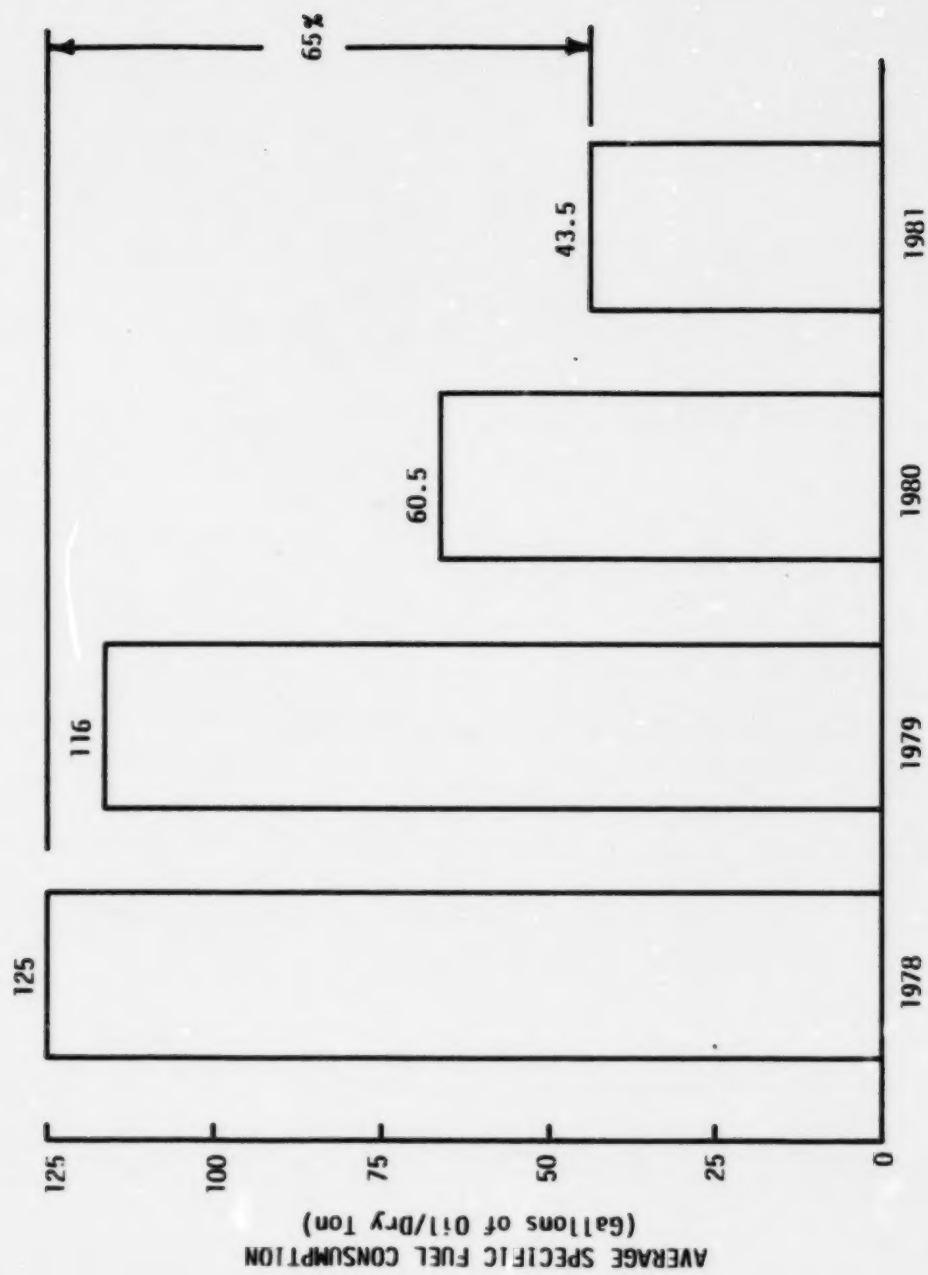


Figure 3. Specific Fuel Consumption Reduction From Belt Filter Press Conversion

COST SAVINGS

Prior to the installation of the belt presses, Hartford's sludge dewatering facility was equipped with five vacuum filters, three of which were in constant operation. The average specific fuel consumption when only vacuum filters were being used was 125.2 gallons of oil per dry ton of sludge cake incinerated. With the presses, the 1981 fuel consumption averaged 43.5 gallons of oil per dry ton. Based on oil of \$1.00 per gallon, the fuel cost savings was \$81.70 per dry ton! With a 1982 production of 10,351 dry tons of sludge cake, the cost savings from changing from vacuum filters to belt presses amount to over \$845,000 for 1982 compared to 1978. Other major savings were also achieved in other plant process areas as result of the change to belt filter presses.

Since the plant started up in 1972, the activated sludge mixed liquor suspended solids (MLSS) concentration had averaged 4,000 to 5,000 milligrams per liter (mg/l) requiring approximately 100 million cubic feet of dissolved air per day. With the belt filter presses, the sludge production increase has enabled the MLSS level to be lowered to a more desirable 2,000 mg/l range. The resulting decrease in the dissolved oxygen demand reduced the daily air usage to approximately 55 million cubic feet per day. This reduction, in turn, reduced the electrical energy requirements of the 3,000 hp air compressor by 20% which amounted to a \$200,000 per year savings in electrical costs.

Also, each vacuum filter had a 71.5 hp requirement as compared to 22 hp for each belt press. This reduction in electricity demand resulted in an estimated savings of \$25,000 per year. In addition, the elimination of vacuum pumps resulted in an annual savings of \$6,000.

The total estimated cost savings of Hartford's conversion to belt filter presses was approximately \$1.08 million per year.

SECTION 6

NEW INCINERATOR OPERATING MODE

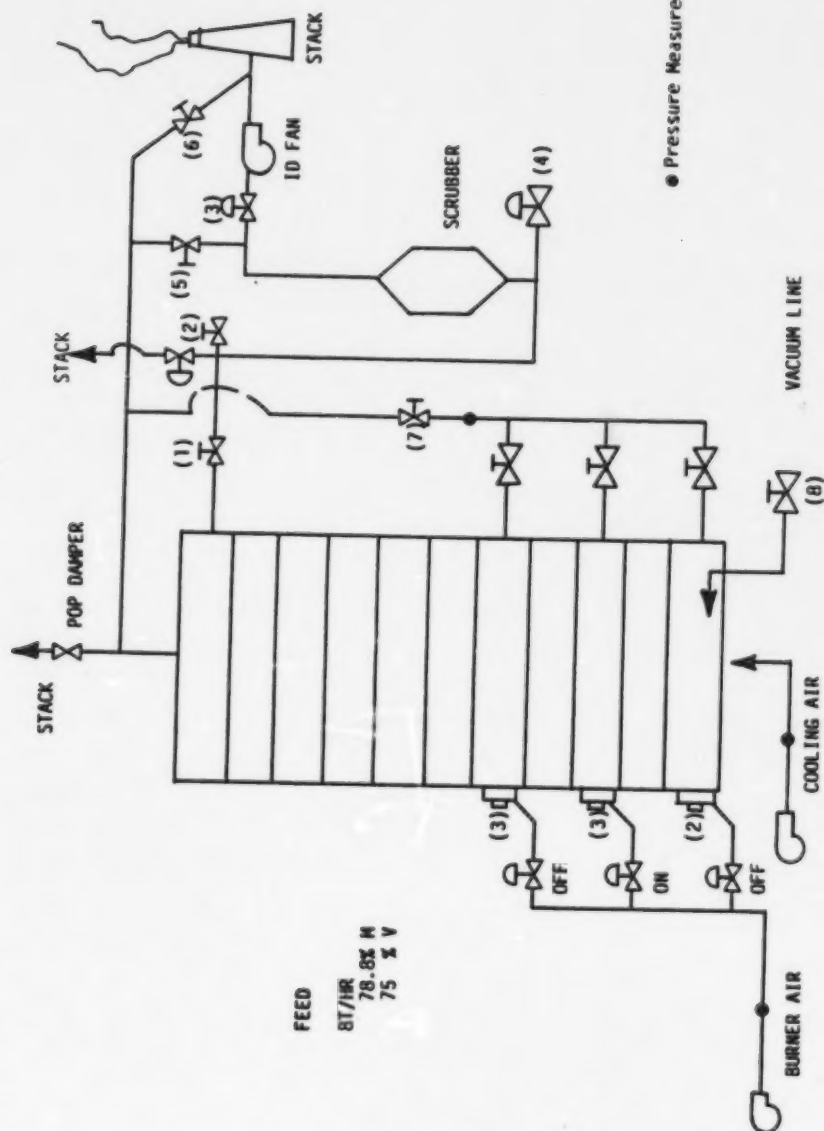
A more fuel-efficient operating mode was developed for the Hartford incinerator operations from an extensive program of combustion engineering measurement, testing, and operational analysis. The development and testing of the new operating mode was the result of a cooperative effort by the Hartford plant engineering staff and personnel with the Indianapolis Center for Advanced Research. The new operating mode was derived from incinerator operating technology developed by ICFAR and the City of Indianapolis under the sponsorship of the U. S. EPA Municipal Environmental Research Laboratory.

OPERATIONAL MEASUREMENTS AND ANALYSIS

Principle airflows of the incinerators were measured to help determine the airflow management approach that was being used in the Hartford operations. Ducted airflows for the cooling air return, cooling air fan discharge and the burner airflow were measured using pitot/static pressure probes and sensitive pressure gauges as illustrated in Figure 4. Each of these ducts were traversed to measure the velocity profile to obtain a more accurate airflow measurement. In addition to these measured flows, the following airflows were estimated: hearth #11 auxiliary air duct, hearth door and peep hole air leaks, burner register airflows, and lance hole airflows. These flows were determined from estimated flow areas and furnace draft. Air entering hearths #1 through #5 was considered "overfire" air, and air entering hearths #6 through 11 was considered "underfire" air.

The incinerator operating set-up when these airflow measurements were made was basically in an improved operating mode with lower draft as compared to past operating modes (e.g. 0.06 inches of water vs. 0.20 in the past) and lower airflow. This set-up was the result of advanced use of draft operation techniques suggested to the Hartford plant engineer prior to initiating the program. The incinerator airflow at the combustion zone level was 6.77 lb_m/sec. The sludge cake volatile flow based on an estimated moisture and volatile of 78.8% and 75%, respectively, is 0.707 lb_m/sec. The stoichiometric air based on 7.41 lb_m of air per lb_m of volatile (CH_{1.61}O_{0.46}N_{0.03}) is 5.24 lb_m/sec. Therefore, the excess air based on the airflow measurements was 29% which appeared reasonable at the operating conditions and from flame observation at the combustion level.

The measured burner airflow was found to be within range of the burner air specifications. The expected flow from three burners was 0.87 lb_m/sec, whereas, the measured flow was 1.04 lb_m/sec.



● Pressure Measurement Locations

Figure 4. Pressure Measurement Locations

The measured cooling fan flow was also found to be in reasonable agreement with the specifications of 8.9 of 10.6 lb_m/sec. The higher measured reading was most likely related to a lower system back pressure condition which existed on the Hartford incinerators due to the position of an auxiliary bypass damper in the exhaust stack.

The airflow inventory results indicated how much of the heated cooling air returned could be used at typical operating conditions. The minimum underfire air leakage from the burner registers, hearth doors, peep and lance holes was estimated to be 1.0 lb_m/sec. The air requirements for a typical load of 6 wet tons of cake per incinerator per hour, with 20% solids and average volatiles with 20% excess air at the combustion zone, would be 4.7 lb_m/sec. The heated cooling return air could supply 3.7 lb_m/sec of the additional air required and still have 65% of its flow ($10.6 - 3.7 = 6.9$ lb_m/sec) being unused and wasted to the atmosphere. This wasted cooling air represented a significant energy loss. The amount of cooling air was then reduced by adjusting the cooling air return fan.

The airflow results were used to help assess various fuel reduction concepts from airflow management alone such as: low draft, closed burner registers, maximum use of cooling air return, reduced load rates, reduced cooling airflow, and sealed air leaks. Preliminary estimates of the potential fuel reduction from these measures was 71% with a sludge cake having a M/V ratio of 5.0 and a load rate of 6 wet tons per hour.

Kinetic Rate Analysis

An incinerator analytical model was employed to predict the lowest possible, or potential, fuel consumption obtainable by optimum incinerator operation. This model was developed by ICFAR from work done on the Indianapolis incinerator operations. The model predicts incinerator fuel requirements on the basis of completing all incineration processes including sludge cake drying, combustion, and ash cool-down in the available incinerator volume. The model is kinetic and calculates, integrates and iterates on gas temperatures, composition, and heat transfer rates which vary throughout the incinerator to arrive at a process-rate-determined solution.

The analytically predicted optimum specific fuel consumption for the Hartford incinerators running a load of 6 wet tons per hour of sludge cake with an M/V ratio of 5.5 or less was 0! This analytical result was in agreement with the preliminary estimate drawn from the airflow management techniques which could reduce the fuel consumption by 71%. The additional 29% could be reasonably expected from using the optimum combustion zone location in the incinerator, optimum burner use profile and the synergistic effect of these operating mode techniques on fuel consumption. Based on these results and ICFAR's previous experiences in Indianapolis and Nashville, the project team expected to see at least some periods of autogenous combustion in the operational testing and implementation phases of the program.

NEW OPERATING MODE

A new operating mode was developed by ICFAR in consultation with Hartford officials. A preliminary set of specific operating instructions which constituted the new operating mode were trial tested and refined. The revised operating mode was then demonstrated in full plant operation for a two week performance test period. After completing the two week demonstration test, the operating mode was further refined for routine operational use.

The new full operational mode was characterized by the following general operating procedures:

- Maximum use of cooling air return to minimize hot air heat loss
- Low top draft to minimize air leakage
- Replace cold auxiliary air supply by returning heated rabble arm cooling air
- Slow center shaft speed to increase sludge drying area
- Low excess air to minimize air heat loss
- Sludge combustion on hearth 7 or 8 to maximize drying temperature
- Eliminate airflow to top burners to maximize drying temperature
- Underfire and overfire burner use profile to control maximum temperature and avoid clinker formation
- Discontinue use of the hearth #5 burners
- Use oxygen analyzer to anticipate possible onset of "burn-outs" caused by very dry sludge cake

The new operating mode instructions given to the Hartford operators are summarized in Figures 4 and 6 and Tables 5 to 10. The procedures cover incinerator sludge load management, incinerator control, general operating settings, specific settings for normal operations, controlling combustion zone and "burn-outs", standby and start-up operations. The most effective dewatering/incineration mode was determined from the trial and demonstration tests to be two belt filter presses feeding one incinerator. The most optimum incinerator loading rate was 6 wet tons of cake per incinerator hour based on trial test of load rates between 4.5 and 7 wet tons associated with keeping up with the overall plant loading and considering the sludge cake M/V ratio with various incinerator-belt press arrangements.

FUEL REDUCTION RESULTS

Demonstration Test Results

A two week performance demonstration test of the new operating mode was conducted by ICFAR combustion engineers with the Hartford incinerator operators. Two incineration/dewatering combinations were tested. During the first week, one incinerator was operated with sludge cake feed being supplied by two belt filter presses, while during the second week, two incinerators were operated and fed by three belt presses. During the two week, 24 hour-a-day test period, on-the-job training was given to the incinerator operators on the use and the techniques associated with the new operating mode. The new operating mode was also further refined during the tests and other equipment

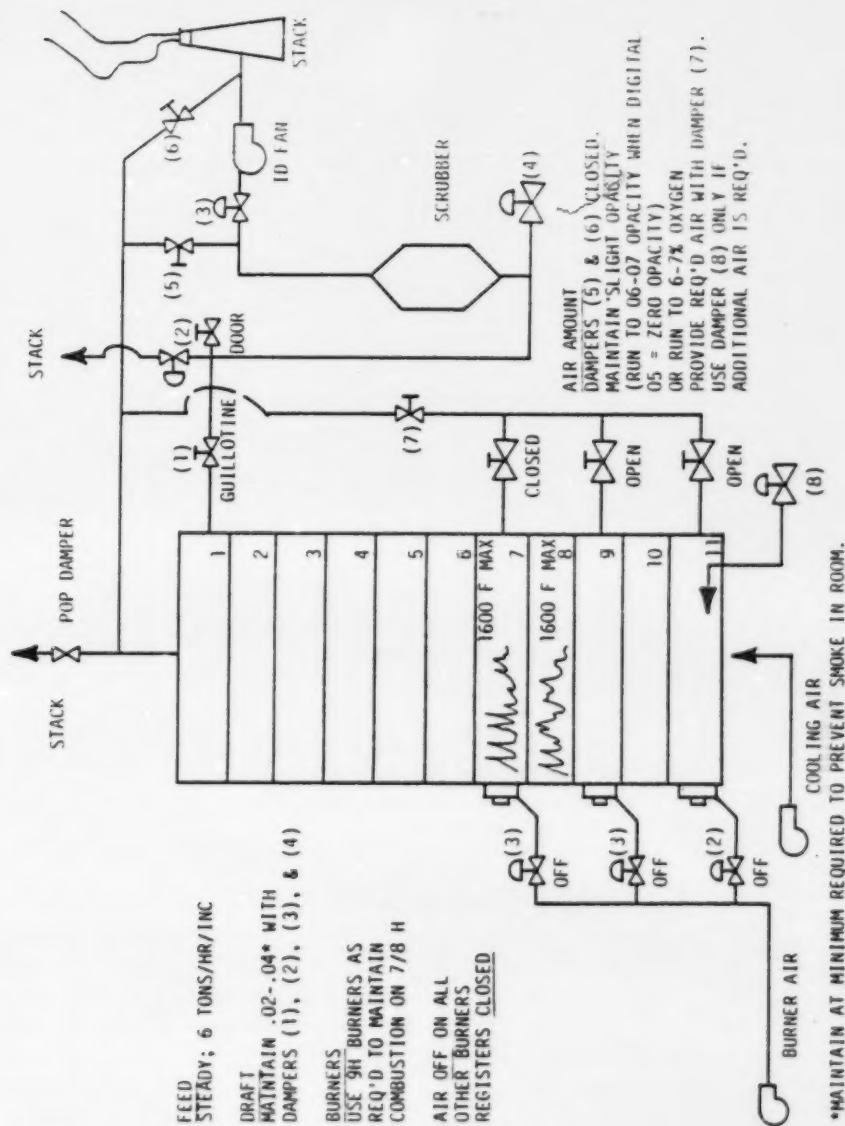


Figure 5. Incinerator Operating Mode Summary

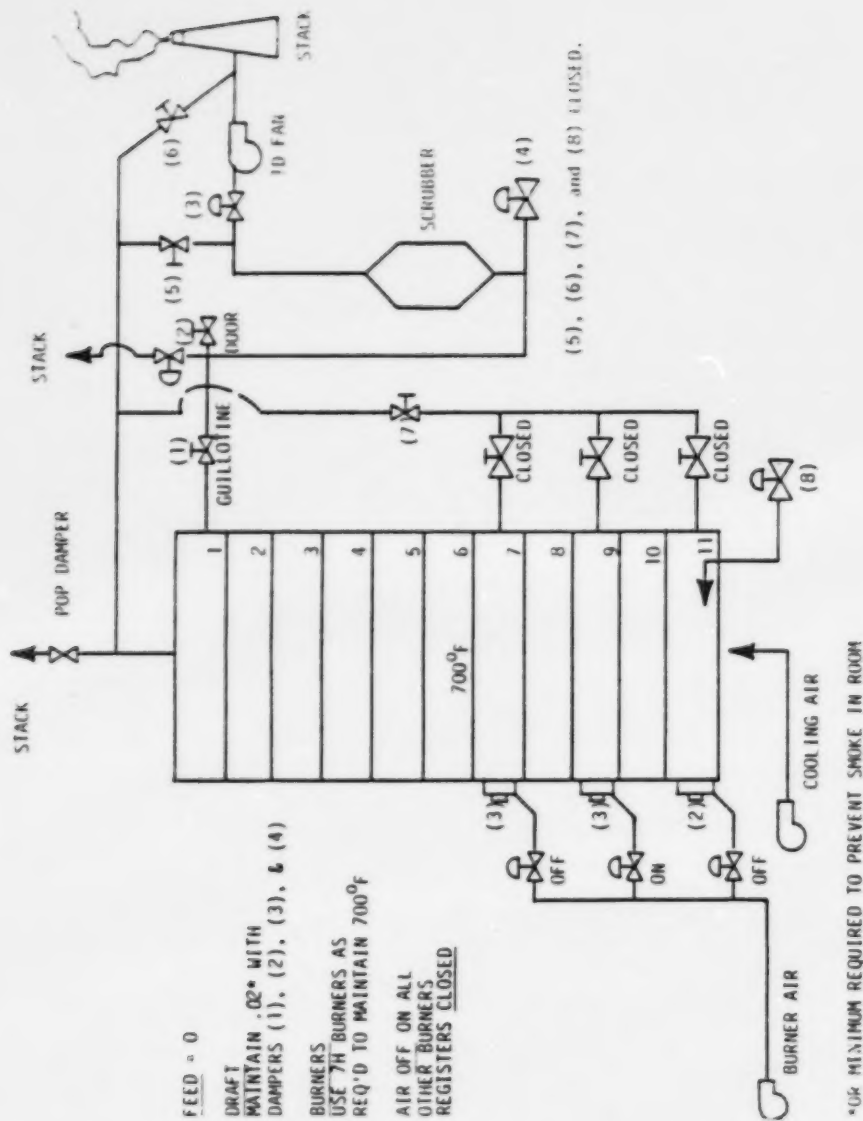


Figure 6. Incinerator Standby Operating Mode Summary

TABLE 4. OVERALL OPERATIONAL GUIDELINES

1. MAINTAIN CONSTANT SLUDGE BLEND.
2. OPERATE INCINERATOR(S) AT 6 WT/HOUR/INCINERATOR.
3. USE 2 BELT FILTER PRESSES PER INCINERATOR WHENEVER POSSIBLE.
4. MAXIMIZE TIME PERIOD OF SINGLE INCINERATOR OPERATION. KEEP SECOND INCINERATOR COLD TO MINIMIZE STANDBY FUEL.
5. USE TWO INCINERATORS AS REQUIRED TO PROCESS SLUDGE INVENTORY.

TABLE 5. INCINERATOR CONTROL SUMMARY

<u>VARIABLE</u>	<u>CONTROL METHOD</u>
<u>SLUDGE LOAD</u>	FILTER OPERATOR
<u>1 HEARTH DRAFT</u>	DAMPERS (1), (2), (3), AND (4)
<u>EXHAUST OXYGEN OR OPACITY (EXCESS AIR)</u>	AIR ENTRY DAMPER SETTINGS: • COOLING AIR RETURN DAMPER (7) • 11 HEARTH AIR DAMPER (8)
<u>SLUDGE COMBUSTION LEVEL</u>	BURNER FIRING RATE
<u>MAXIMUM TEMPERATURE (CLINKERING)</u>	• UNDERFIRE* BURNER FIRING RATE • EXHAUST OXYGEN (EXCESS AIR) • COOLING AIR UTILIZATION

*BELOW SLUDGE COMBUSTION LEVEL

TABLE 6. GENERAL OPERATING PROCEDURE

1. MAINTAIN STEADY 6 TONS PER HOUR PER INCINERATOR
2. MAINTAIN DRAFT OF .02 - .04 IN WATER ON TOP OF 1 HEARTH
(OR MINIMUM REQUIRED TO PREVENT ROOM SMOKE)
3. ADJUST INCINERATOR AIRFLOW TO:
 - MAINTAIN SLIGHT OPACITY (06-07 WHEN DIGITAL METER ZEROES AT .05)
 - OR
 - MAINTAIN 6-7% EXHAUST OXYGEN (WET BASIS)
4. MAINTAIN SLUDGE COMBUSTION ON 7 OR 8 HEARTH
5. USE ONLY 9 HEARTH BURNERS IF REQUIRED
6. LIMIT MAXIMUM TEMPERATURE TO 1600°F TO PREVENT CLINKERS

TABLE 7. SPECIFIC SETTINGS FOR NORMAL OPERATION

ITEM	SETTING
FEED RATE - STEADY 6 TONS PER HOUR PER INCINERATOR	
- USE 2 PRESSES FOR 1 INCINERATOR	
- USE 3 OR 4 PRESSES FOR 2 INCINERATORS	
- NEVER USE VACUUM FILTER	
CENTER SHAFT - MAINTAIN 40% (50 SEC PER REVOLUTION)	
COOLING AIR - RETURN TO 9 AND 11 HEARTHS ONLY. VARY AS REQUIRED USING DAMPER (7) TO CONTROL:	
	• OPACITY TO 06 - 07 (WHEN DIGITAL METER ZEROES AT 05) • EXHAUST OXYGEN TO 6-7% (WET BASIS)
11 H AIR - USE ONLY IF MORE AIR IS REQUIRED THAN AVAILABLE FROM COOLING RETURN	
DOORS/PEEPS/LANCE HOLES - CLOSED TIGHT ON ALL LEVELS.	
BURNERS - ADJUST OVERALL FIRING RATE TO BURN SLUDGE ON 7 OR 8 HEARTH.	
- USE ONLY 9 H BURNERS IF REQUIRED	
- KEEP AIR REGISTERS CLOSED ON ALL BURNERS.	

TABLE 8. RISING FIRE AND "BURNOUT" CONTROL TECHNIQUES

RISING FIRE

CAUSE: EXCESSIVE SLUDGE DRYING RATE RELATIVE TO FEED RATE

ACTION: 1. REDUCE BURNER FIRING RATE

2. INCREASE FEED RATE
RE-ESTABLISH COMBUSTION ON 7 OR 8 HEARTH.

BURNOUTS

CAUSE: RAPID INCREASE IN SLUDGE DRYING RATE CAUSED BY INCREASED SLUDGE BURNING

APPROACH: BEST APPROACH IS PREVENTION. ANTICIPATE BURNOUT FOLLOWING A LOAD REDUCTION. CLOSELY MONITOR EXHAUST TEMPERATURE; AN INCREASE INDICATES INCIPENT BURNOUT. TAKE FOLLOWING ACTION TO CONTROL PROCESS:

1. SHUT-OFF BURNERS AT ONCE.
2. INCREASE CENTER SHAFT SPEED IF REQUIRED TO CONTROL TEMPERATURE INCREASE.
3. WORK BACK TO NORMAL OPERATING CONDITION.

APPROACH TO FULL-BLOWN BURNOUT:

1. OPEN DOORS ABOVE FIRE TO REDUCE TEMPERATURE
2. SPEED CENTERSHAFT TO REDUCE DRYING TIME OR REDUCE SHAFT SPEED TO REDUCE BURN RATE
3. OPEN DOORS UNDER FIRE TO CONTROL SMOKE.

TABLE 9. DROPPING FIRE CONTROL TECHNIQUES

CAUSE: INSUFFICIENT SLUDGE DRYING RATE RELATIVE TO FEED RATE

ACTION: (1) INCREASE BURNER FIRING RATE AND/OR
(2) REDUCE FEED RATE

MILD DROP (FIRE ON 8 HEARTH) - (1) INCREASE BURNER FIRING RATE BY APPROXIMATELY 25%
(2) REDUCE FIRING RATE AS FIRE CLIMBS TO 7 HEARTH

SEVERE DROP (FIRE ON 9 HEARTH) - (1) INCREASE FIRING RATE BY 50 - 100%
(2) REDUCE SHAFT SPEED TO 0.50 RPM IF POSSIBLE
(3) REDUCE SLUDGE FEED RATE
(4) RETURN TO STABLE CONDITION AS FIRE CLIMBS

LOST IT (SLUDGE IN BSMT.) - (1) STOP FEED
(2) CLEAR INCINERATOR
(3) RE-ESTABLISH FEED
(4) WORK TO STABLE CONDITION

TABLE 10. STANDBY OPERATION AND START-UP PROCEDURE

STANDBY (NO FEED)

1. BURN OUT ALL SLUDGE
2. SHUT-OFF ID FAN
3. MINIMIZE INCINERATOR AIRFLOW
 - SET DRAFT TO .02* IN WATER ON TOP OF 1 HEARTH
 - EXHAUST ALL COOLING AIRFLOW; CLOSE DAMPER (7)
 - CLOSE ALL DOORS, PEEPS, AND AIR ENTRY DAMPERS
 - SHUT OFF BURNER AIRFLOW ON 9 AND 11 HEARTH
4. ADJUST 7 HEARTH BURNERS TO MAINTAIN 700°F ON 6 HEARTH.

START-UP FOR SLUDGE COMBUSTION AT 0200 HOURS

1. 1900 HOURS - LIGHT (3) 9 HEARTH BURNERS TO 700°F (AUTOMATIC SET POINT)
SHUT-OFF 7 HEARTH BURNERS
2. 2000 HRS - INCREASE 9 HEARTH BURNER SET POINT TO 800°F
3. 2100 HRS - INCREASE 9 HEARTH BURNER SET POINT TO 1000°F
4. 2200 HRS - INCREASE 9 HEARTH BURNER SET POINT TO 1100°F
5. 2300 HRS - INCREASE 9 HEARTH BURNER SET POINT TO 1200°F
6. 2400 HRS - INCREASE 9 HEARTH BURNER SET POINT TO 1300°F
7. 0200 HRS - INITIATE FEED AT 3 WET TONS/HOUR. START ID FAN, OPEN 9 AND 11 H COOLING RETURN DAMPERS
8. 0300 HRS - INCREASE SLUDGE FEED TO 6 WET TONS/HOUR FOLLOW NORMAL OPERATING PROCEDURE

*OR MINIMUM REQUIRED TO PREVENT SMOKE IN ROOM

and instrumentation changes were identified that would help improve operator performance and control.

To provide a baseline measure of the fuel reduction achieved by the new incinerator operating mode separate from the reductions achieved with the belt filter presses, a statistical analysis of the baseline operational data was made for the period June 1, 1980 through August 31, 1981 (15 months) after three presses had been installed. The computed correlations of specific fuel consumption (gallons of oil per dry ton) versus incinerator load rate and sludge cake moisture to volatile ratio for the baseline period are shown in Figures 7 and 8, respectively. These highly correlated relationships were used to correct, or adjust, for comparison the specific fuel consumption achieved during the demonstration test to the same loading rates and sludge cake M/V ratios to the baseline period. The daily average values of the key incinerator operating variables for the baseline period by month are shown back in Table 2 and by incineration/dewatering mode in Table 3.

The two-week demonstration test was conducted in January, 1982. The overall demonstration test fuel reduction results are shown in Figure 9 along with the results by incineration/dewatering mode. The direct specific fuel reduction achieved was 76%. The one incinerator-two press mode was also found to be more fuel efficient than the two incinerator-three press mode. When the results are corrected to comparative baseline load rates, the percent fuel reduction was even greater as shown in Figures 10 and 11. The overall result was 79.8%, and a greater differential existed between the two plant operating modes with the one incinerator-two press combination registering an 82% reduction with an average specific fuel consumption of 8.5 gallons per dry ton! If this SFC is compared to the historical average of 125.2 for Hartford before the presses or incinerator operating mode was changed, the total percent fuel reduction was 93%! This result further reinforced the Hartford decision to buy a fourth press and operate with two presses-one incinerator pairs.

The demonstration test fuel reduction results were also compared with a correction for the sludge cake M/V ratio as previously discussed. With the M/V ratio correction, the overall percent fuel reduction was 53.2%. The daily test results corrected for M/V ratio are shown in Figure 12. Also shown is the potential fuel reduction that still exists in the Hartford incinerator operations. Even though the results of the demonstration test were very significant, the minimum fuel consumption levels possible were not achieved for several equipment related reasons. There was an uneven sludge distribution problem through the incinerator because of the rabble arm pattern for raking the sludge. A distorted burning pattern with sludge combustion occurring on three hearth levels at the same time with uneven burning on one side of these hearths was encountered several times. This condition probably was created by a rabble arm pattern originally set up for wetter sludge cake (M/V=8) now being used to burn sludge cake with an M/V = 4.5 which requires an entirely different rabbling pattern. This equipment set up is going to be corrected by Hartford with the incinerator manufacturer. Also, to a lesser extent, the demonstration test was conducted with the main test incinerator having a faulty return air system which reduced overall fuel efficiency.

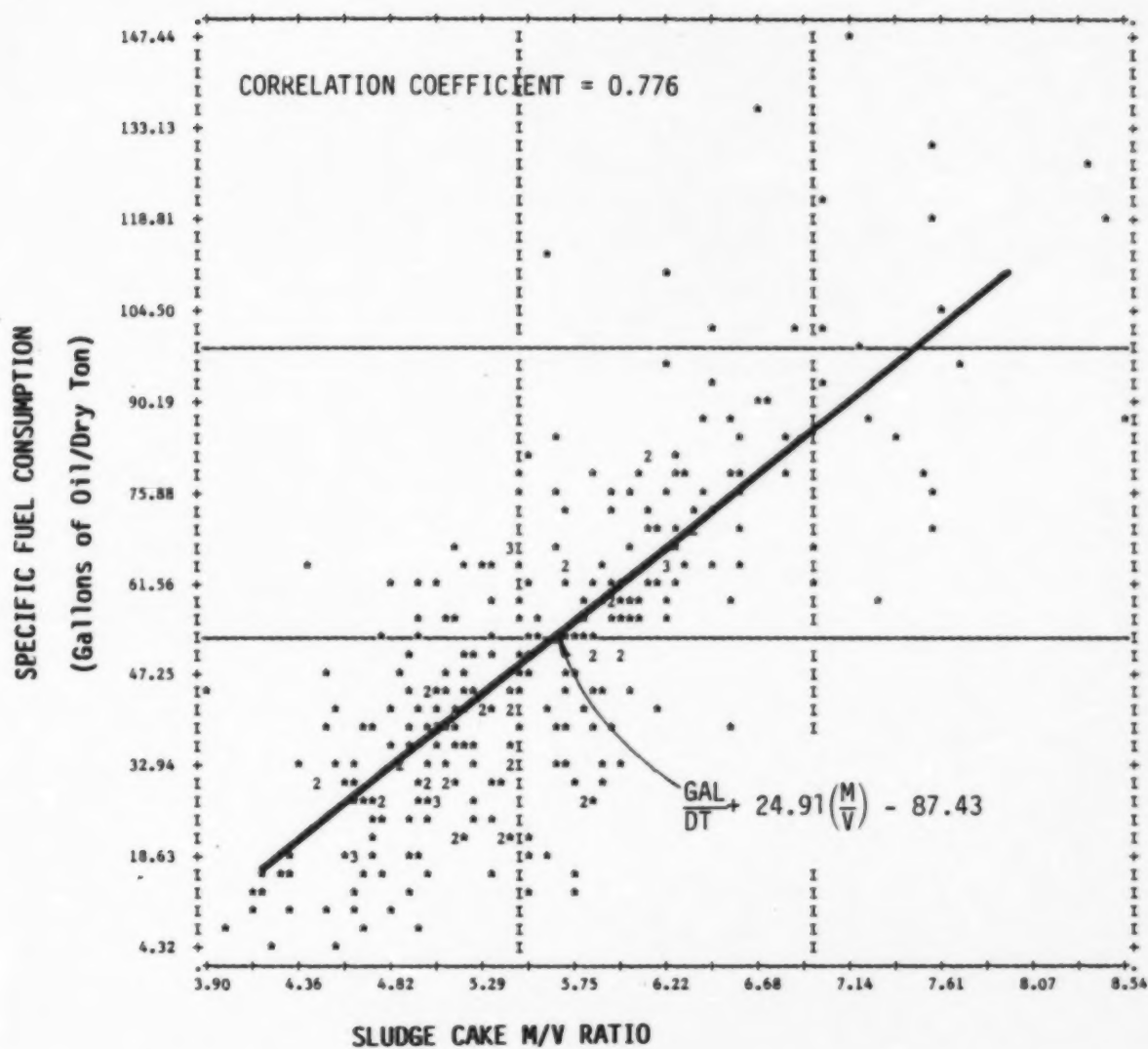


Figure 8. Correlation of Specific Fuel Consumption With Sludge Cake Moisture To Volatile Ratio for the Baseline Period

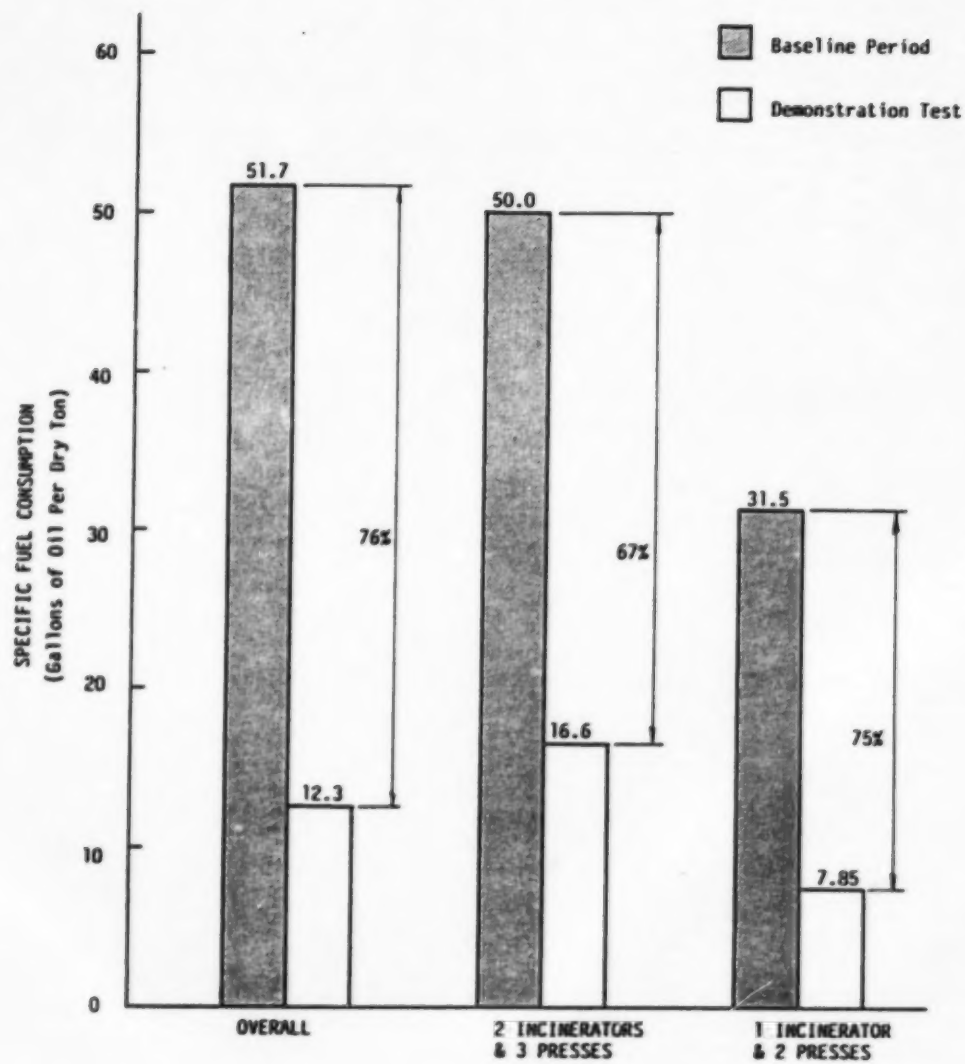


Figure 9. Overall Demonstration Test Fuel Reduction Results

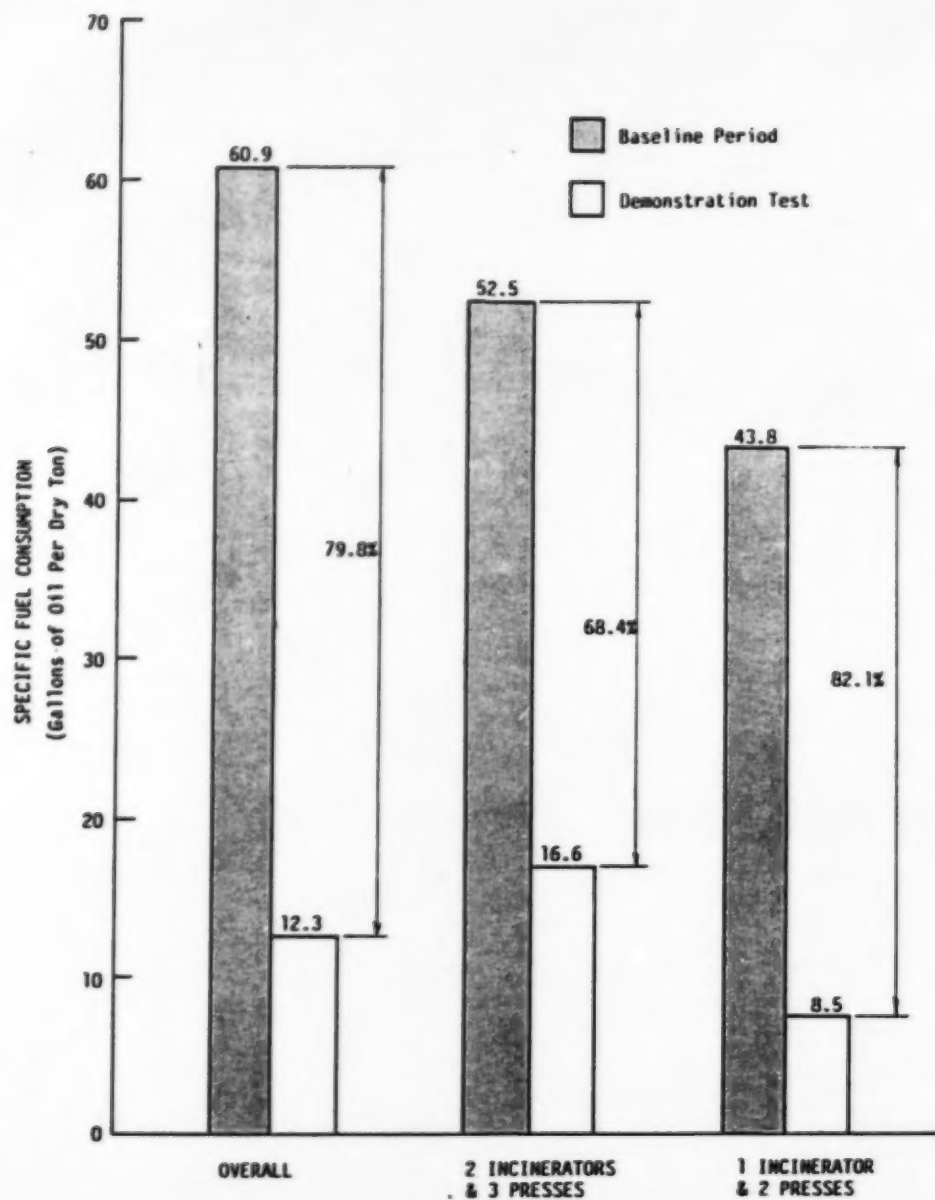


Figure 10. Demonstration Test Fuel Reduction Results by Operating Mode With Load Rate Correction

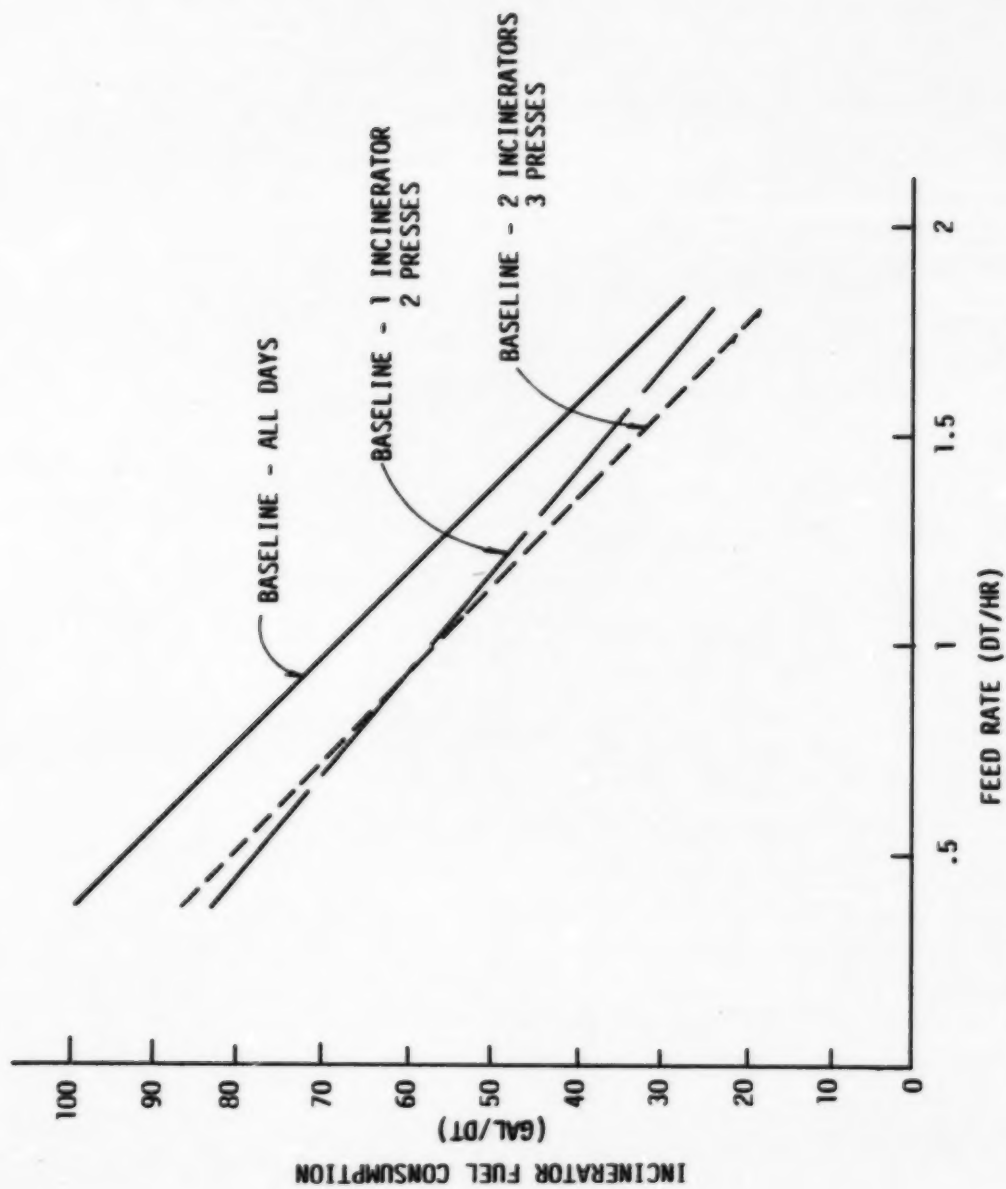


Figure 11. Demonstration Test Fuel Reduction Results by Incinerator Load Rate

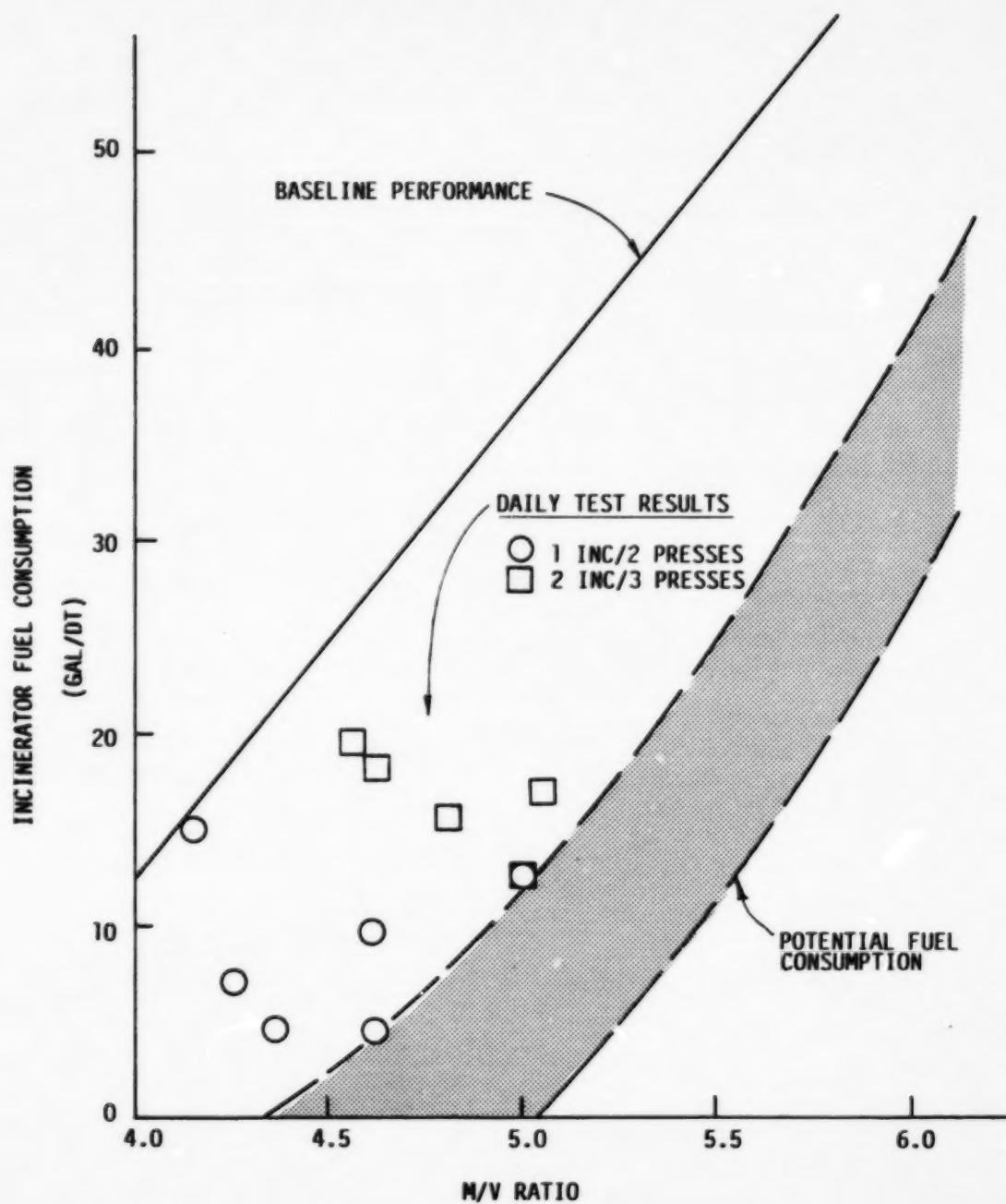


Figure 12. Demonstration Test Fuel Reduction Results by Sludge Cake M/V Ratio

Routine Operational Results

The new incinerator operating mode has been routinely used by the Hartford incinerator operators through the full year of 1982 since the demonstration test was conducted. The operational data for the Hartford plant for 1982 was analyzed to measure and compare the fuel reduction achieved with the use of the new operating mode. The specific fuel consumption versus sludge cake moisture/volatile ratio correlation result for 1982 is shown in Figure 13 superimposed on the "before" baseline experience. The change in the slope of fuel used per dry ton indicates the improved thermal efficiency of the new operating mode as compared to the old mode. This result is similar to what occurred in both Indianapolis and Nashville, Tennessee when the basic incinerator operating mode was improved. The average specific fuel consumption for Hartford during 1982 was 21.1 gallons of oil per dry ton as compared to an average of 51.7 for the 15 month baseline period. The overall fuel reduction on this basis was 59% or about 30 gallons of oil per dry ton.

The above comparisons of average fuel consumption used the baseline period for consistency which covers a 15 month period in 1980-1981. The average specific fuel consumption in 1981 was 43.5 gallons per dry ton. In comparing 1982 to 1981, the average fuel reduction was 22.4 gallons per dry ton, or 52%. The magnitude of this fuel reduction is very significant considering the major reductions that had already been achieved by Hartford in converting to belt filter presses.

COST SAVINGS

The fuel cost savings as a result of the new operating mode used in 1982 was estimated by multiplying the total dry tons incinerated by the net reduction in the average specific fuel consumption (30.6 gallons/dry ton). The total dry tons incinerated in 1982 were 10,351. This would amount to an annual fuel savings of 316,740 gallons of fuel oil as compared to the 1980-1981 period. In comparison with 1981, the fuel savings were 231,862 gallons of oil. At the current nominal price of \$1.00 per gallon, the total annual savings as compared to 1981 was over \$230,000.

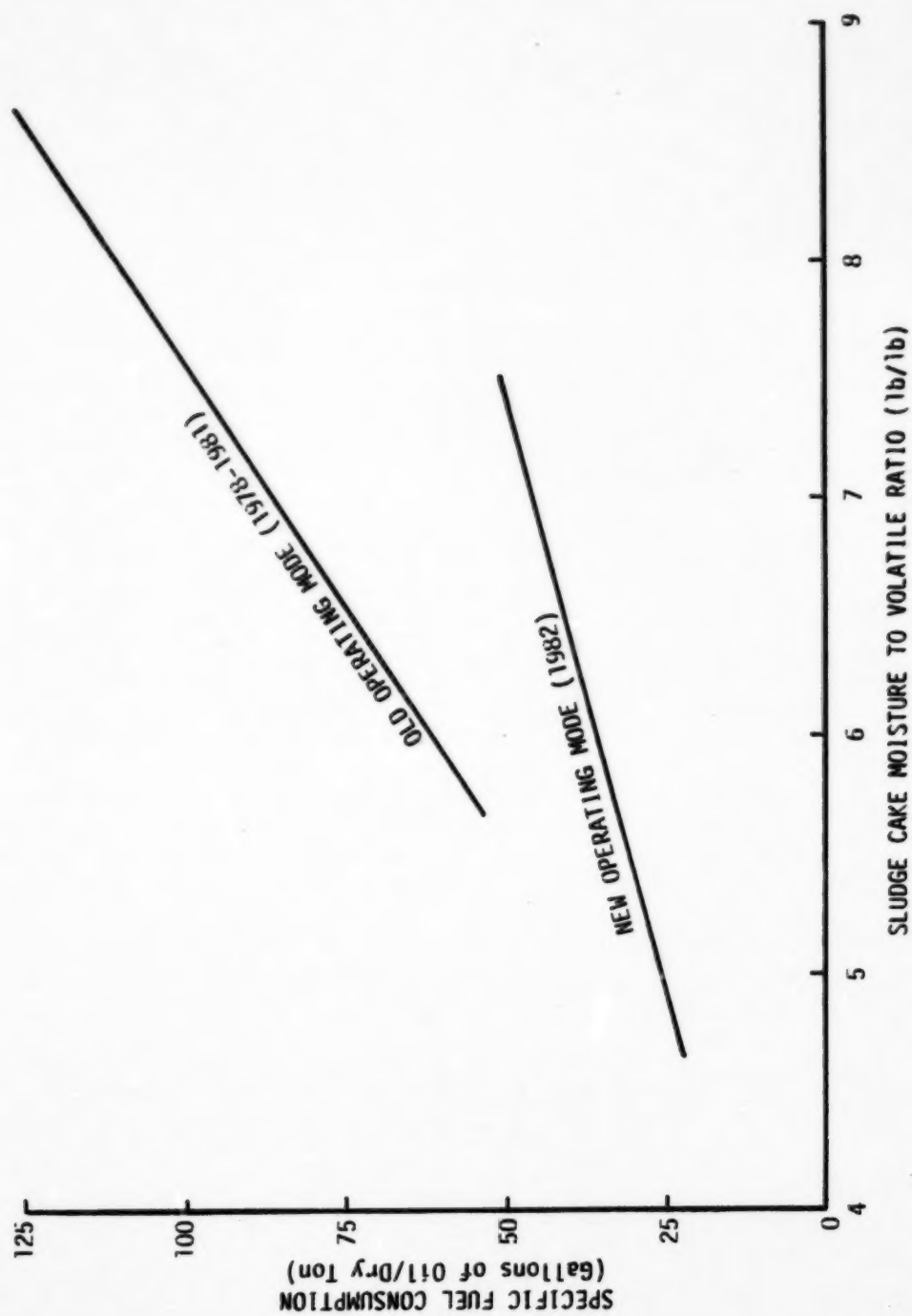


Figure 13. Specific Fuel Consumption Versus Sludge Cake M/V Ratio Before and After Incinerator Operating Mode Change

SECTION 7

TOTAL FUEL REDUCTION AND COST SAVINGS

TOTAL FUEL REDUCTION

Shown in Figure 14 is the average yearly specific fuel consumption in gallons per dry ton for the Hartford incinerator operations for the years 1978 through 1982 at the average sludge cake moisture to volatile ratios recorded for these years. The same data are also shown in Table 11 below.

TABLE 11. AVERAGE SPECIFIC FUEL CONSUMPTION AND SLUDGE CAKE M/V RATIO FOR 1978-1982

<u>Year</u>	<u>Specific Fuel Consumption (Gallon/Dry Ton)</u>	<u>Sludge Cake M/V Ratio</u>
1978	125.2	8.6
1979	116.1	8.2
1980	60.5	5.8
1981	43.5	5.4
1982	21.1	4.8

The total percent fuel reduction from 1978 to 1982 was 83%. This dramatic reduction of 104 gallons per dry ton represents a fuel savings for 1982 production of over 1,076,000 gallons of fuel oil as compared to 1978 operations. The savings resulting from the belt filter presses is reflected in the sharp reduction in the sludge cake moisture to volatile ratio which made its greatest change in 1980, dropping by about 29% from the year before with a corresponding drop in fuel consumption of 56 gallons/dry ton. Further improvement in 1981 was achieved with the installation of additional presses reducing the fuel consumption by another 17 gallons/dry ton. The change in the incinerator operating mode in 1982 resulted in a 22 gallon per dry ton reduction with a two fold effect in improving the fuel efficiency further. There was a basic gain due to the improved thermal efficiency associated with the new operating mode. Also, the optimization of the incinerator loading rates with the resulting balancing of sludge cake feed rates with the one incinerator-two press plant operating mode enabled the presses to be ran at slower rates which improved their performance. This resulted in an additional improvement in the sludge cake M/V ratio.

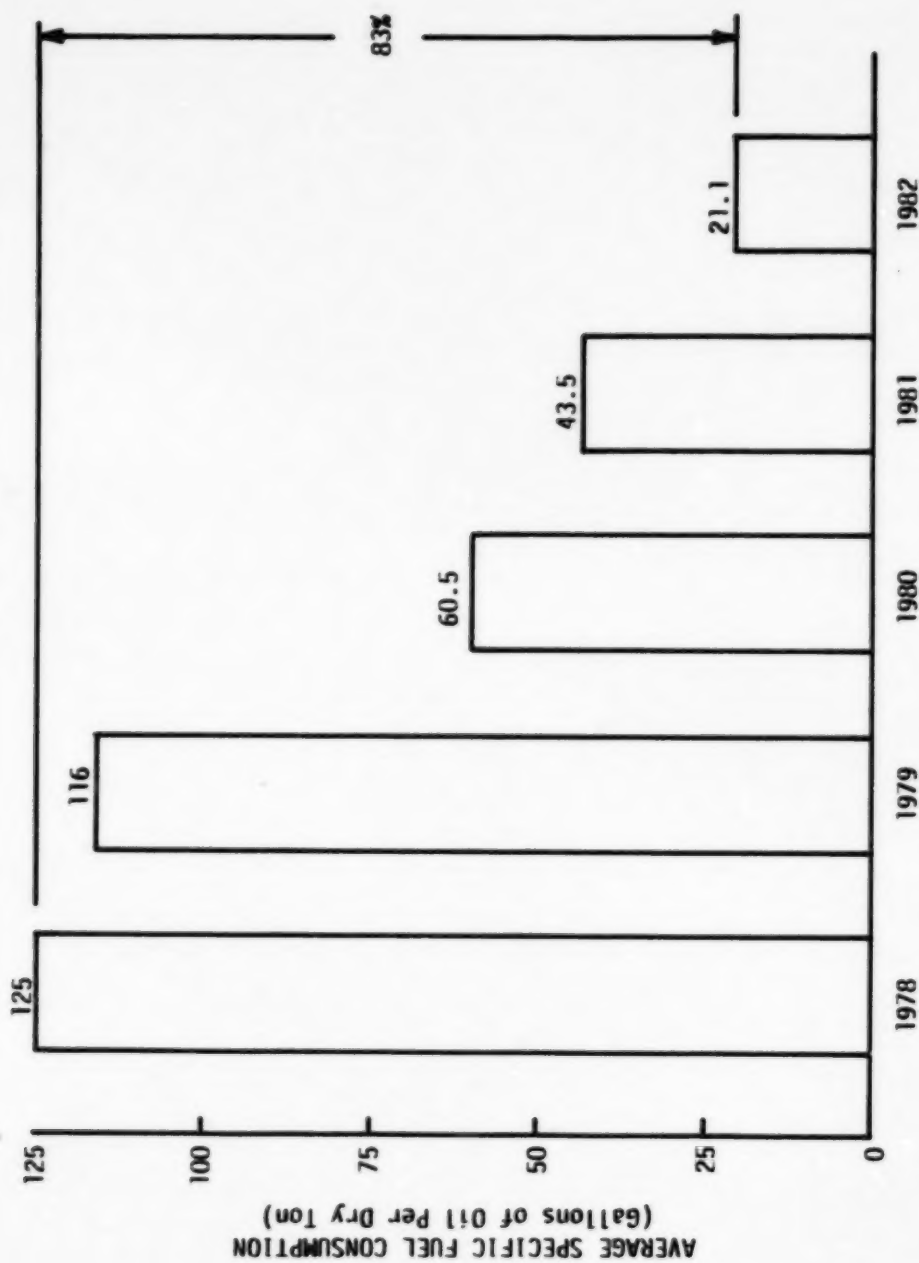


Figure 14. Average Specific Fuel Consumption For 1978 to 1982

TOTAL COST SAVINGS

The historical change from using 125 gallons per dry ton to incinerate the sludge to 21 gallons per dry ton represents a gross operational cost savings for 1982 of more than \$1 million per year compared with what might have been if no change or improvements had been made.

As previously discussed, the cost savings of converting to the belt filter presses had secondary energy saving benefits. An estimated electricity savings of \$231,000 per year having resulted from reduced air compressor requirements, smaller motors for the belt presses as compared to the vacuum filters, and the elimination of the vacuum pumps.

With these component savings, the total cost savings is estimated to be more than \$1.08 million per year compared with 1978.

SECTION 8

COMPARISON OF RESULTS IN FOUR MAJOR CITIES

The improved incinerator operating technology developed by ICFAR in Indianapolis, Indiana, under sponsorship of the U. S. EPA Municipal Environmental Research Laboratory has been incorporated into the routine operations of four major city wastewater treatment plant operations: Indianapolis, Nashville, Tennessee, Hartford, Connecticut and Buffalo, New York. Dramatic reductions in the incinerator fuel consumption in these cities has been achieved with the use of more fuel efficient operating techniques. The demonstration test results in all of the cities have achieved a 50% fuel reduction or more, and routine operational savings of 35% or greater. These hard results which have been accomplished in four different municipal operations suggest very clearly the enormous fuel saving potential which still exists in so many plant operations around the country.

Only a gross comparison of fuel consumption and the reductions achieved by using improved incinerator operating modes can be made between these four city operations because of variations in plant operations, sludge blends, incinerator loading rates, etc. All four cities are incinerating a combination of primary and waste activated sludge. Some general operating features of each plant is shown in Table 12 below.

TABLE 12. KEY OPERATING FEATURES OF SUBJECT CITIES

<u>City</u>	<u>No. of Incs.</u>	<u>No. of Hearths</u>	<u>Capacity Inc/Plant (Tons/Hr)</u>	<u>Dewatering Equipment</u>	<u>Sludge Cake M/V Ratio</u>
Hartford	3	11	12/36	Belt Presses	4.5
Indianapolis	8	8	7/56	Vacuum Filters	7.3
Buffalo	3	12	14/42	Coil Filters	7.8
Nashville	2	10	10/20	Coil Filters	8.7

All of the above incinerators have the same diameter of 22 feet 3 inches. All four cities use polymer for sludge conditioning with Indianapolis also adding recycled incinerator ash to aid cake release from the vacuum filter cloths. Both Indianapolis and Buffalo are currently installing belt filter presses. The Indianapolis, Nashville and Buffalo incinerator operations run on a 24 hour-a-day, seven day-a-week schedule with Hartford operating only five days a week.

The average specific fuel consumption for all four of these cities before and after they started using an improved incinerator operating mode is shown for comparison in Figure 15 with their locations along the abscissa corresponding to their average sludge cake M/V ratio. Table 13 also gives the same information along with the overall percent fuel reduction achieved in each city under routine operational conditions. The specific fuel consumption is given in gallons of oil per dry volatile ton to avoid the variations that might exist on a dry ton basis due to inert material additions in the sludge cake such as in Indianapolis.

TABLE 13. FUEL REDUCTION ACHIEVED IN FOUR MAJOR CITIES FROM IMPROVED INCINERATOR OPERATING MODES

CITY	SLUDGE CAKE M/V RATIO	SPECIFIC FUEL CONSUMPTION (Gallons/Dry Volatile Ton)		PERCENT REDUCTION
		BEFORE CHANGE	AFTER CHANGE	
Hartford	4.5	56.0	30.0	46
Indianapolis	7.3	83.9	33.4	60
Buffalo	7.8	90.9	48.2	47
Nashville	8.7	166.0	101.0	39

Figure 15 illustrates the significant reductions in specific fuel consumption which can be achieved by both dewatering and incinerator operating mode improvements. With Hartford being the only city in the comparison which has completed a dewatering equipment change, the SFC for Hartford in 1978 when only vacuum filters were being used is also shown for comparison. The dramatic reduction accomplished by Hartford with the conversion to belt presses was from an average of 160 gallons per volatile ton down to 52 gallons per volatile ton. Improved dewatering in the other cities would also bring further reductions. Indianapolis and Buffalo are currently installing belt filter presses. The plans in Nashville are not known. Nashville, however, would realize major savings from any improvement in their current dewatering operations.

The reductions achieved by the change in the incinerator operating mode was consistent for all four cities. The change in fuel consumption resulting from using a new operating mode reflects the improved thermal efficiency accomplished with the same equipment through use of more refined operating techniques. The low SFC achieved by Indianapolis is at the expense of throughput capacity since the sludge ash recycling reduces the thermal demand characteristics, but displaces volatile solids in the process. For example, in comparison to Hartford, the dry volatile solids incineration rate in Hartford is about 1 ton per incinerator per hour. Whereas, in Indianapolis, the average is 0.65 tons per hour, or 35% less. The use of belt presses in Indianapolis will then allow the sludge ash recycle to be abandoned, and throughput rates will be improved.

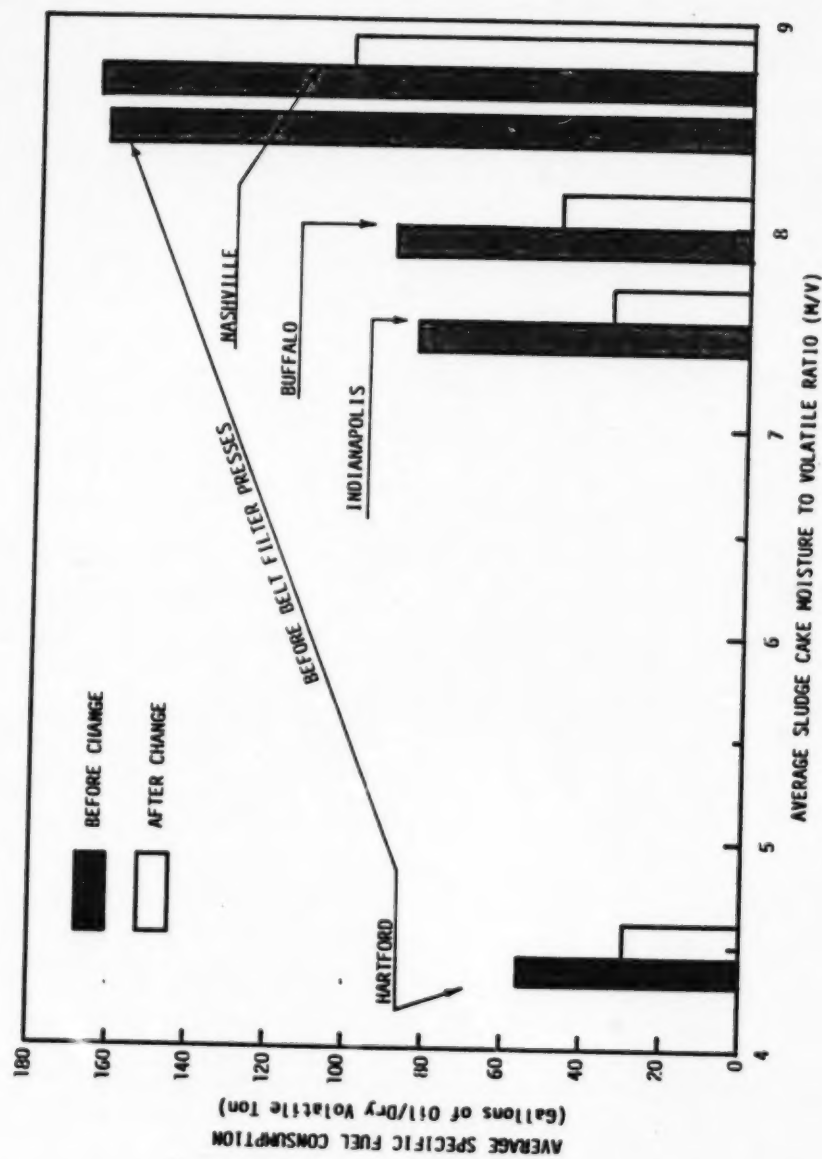


Figure 15. Fuel Consumption After Operating Mode Change in Hartford, Indianapolis, Buffalo and Nashville

For those cities still suffering from high sludge incinerator fuel consumption, the options of both improving dewatering and the incinerator operating mode cannot afford to be ignored. The purchase and installation of new dewatering equipment is expensive and time consuming. However, the pay-back periods in many cases could be less than a year. Changing the incinerator operating mode and component training of the incinerator operators can be accomplished without major capital cost equipment related changes and can be done very quickly to obtain immediate cost savings regardless of the plans for sludge cake dewatering. The savings of the above four cities above from changing only the incinerator operating mode total over \$1,000,000 annually. The time required to accomplish the incinerator operating mode change in each case was less than three calendar months. The results in these four cities can be used as a yardstick to determine if a given operation has fuel savings potential by comparing the current specific fuel consumption at the sludge cake moisture to volatile ratio with these four cities.

In general, as more experience is gained in new dewatering equipment technology, more efficient incinerator operating know-how, and as new incinerator equipment designs which embody more advanced combustion engineering principles comes along, incineration of sludge will still continue to be a viable alternative for sludge disposal for many cities in the future.

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